Rainfall at Urban Hydrological Scales : Opportunist use of TV-SAT Receivers Network

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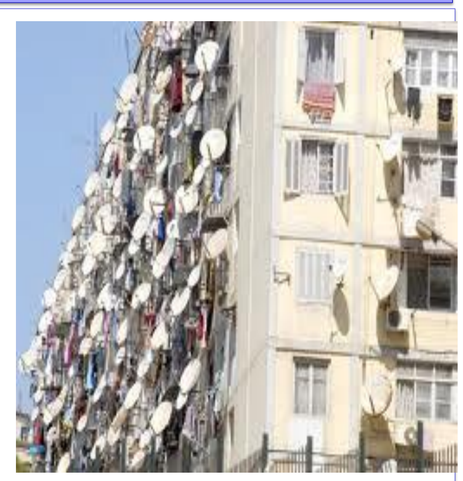
Feasibility Study

A measurement system (Figure 1) allows estimating integrated rain attenuations along satellite-ground links (depending on the freezing level and on the relative position of the satellite from the receiver) with a high temporal resolution (15s) see [Barthes and Mallet (2013)]. A 4D-VAR assimilation algorithm (Figure 2) using an advection numerical scheme has been applied on 4 rain attenuation times series recorded by a single Ku band TV-SAT receiver during HyMeX experiment. The obtained rainfall fields [Mercier et al. (2015)] at resolution 10s and 0.5x0.5 km2 have been validated against co-located radar maps and rain gauges data.



Rain attenuation times series that could be observed along satellite-ground links by a virtual Ku band TV-SAT receivers network located in Guyancourt urban area are simulated. Different Ku receivers network configurations are simulated. The 4D-VAR assimilation algorithm is applied to retrieve corresponding rain fields. Rain fields obtained with the assimilation algorithm applied to a network configuration with 21 and 73 links respectively are compared with original rain field.

Opportunist measurement

The aim of this work is to rebuild rainfall fields at small scale (around $30 * 30km^2$ with $0{,}5 * 0{,}5km^2$ grid boxes) from measures of attenuation of electromagnetic waves. Theses waves come from geostationary TV satellites and are in the Ku band (around $12GHz$).

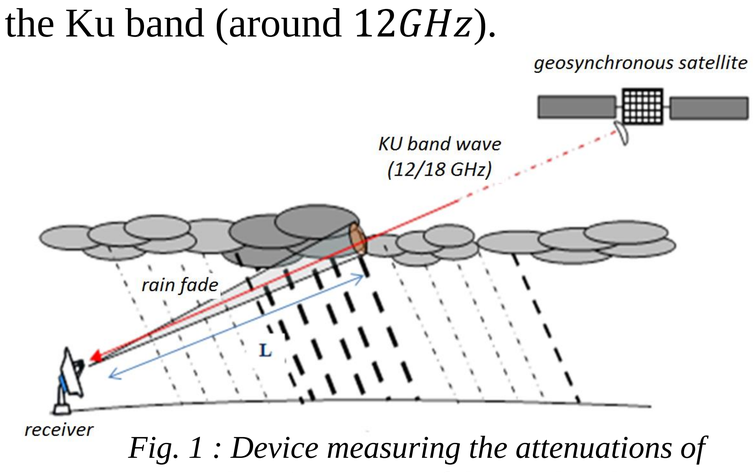


Fig. 1 : Device measuring the attenuations of the microwaves of the KU band

4D VAR Assimilation algorithm using YAO software (LOCEAN)

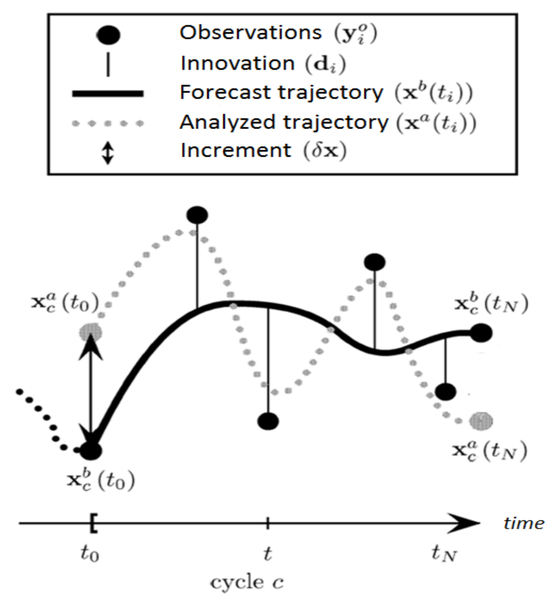


Fig. 2 : Principle of the 4D-VAR data assimilation

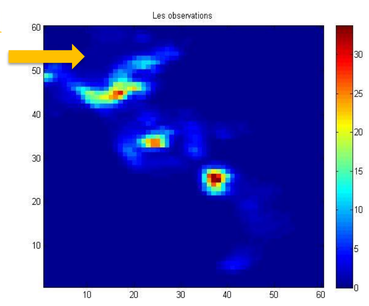
Cost function of the assimilation algorithm :

$$J(R^0) = \underbrace{\sum_{n=1}^{N} \|y_n - HR^n\|^2}_{\text{Gap with the observations}} + \underbrace{\alpha \sum_{n=1}^{N} \left(\sum_{i,j} \left\| R_{ij}^n - \overline{R_{ij}^n} \right\|^2 \right)}_{\text{Filter term}}$$

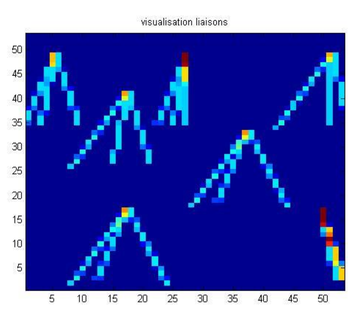
- R^0 is the initial rainfall field discretized on a spatio-temporal grid. R^n is this initial field propagated by an advection numerical scheme from $t_0 = 0$ to $t_n = n\Delta t$
- y_n contains the observations available at time n (rain gages and KU-waves).
- H_n is the operator projecting the field R^n on the observations space at time n
- R_{ij}^n is the mean rainfall around grid point (i, j)
- α is a coefficient to balance the weight of the 2 terms

Results and analysis : configurations 21 links

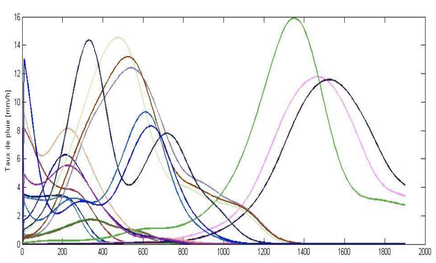
wind



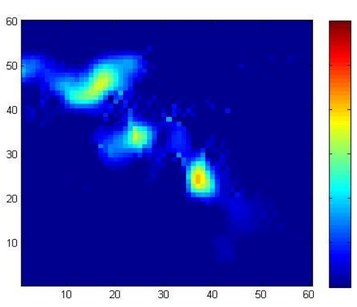
Original simulated rain field (to be rebuilt)



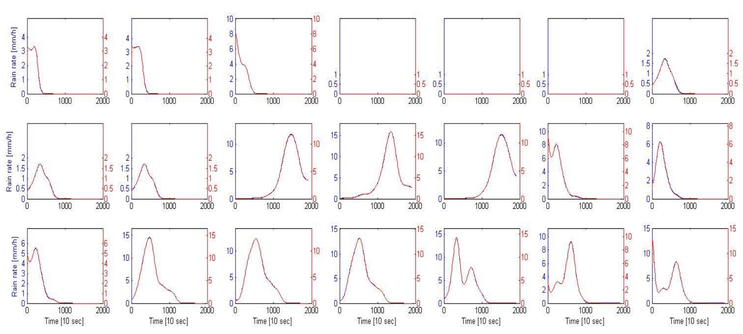
Configuration (7 TV-SAT receivers and 21 links)



Rainfall time series views per 7 links



Retrieved field using 21 links

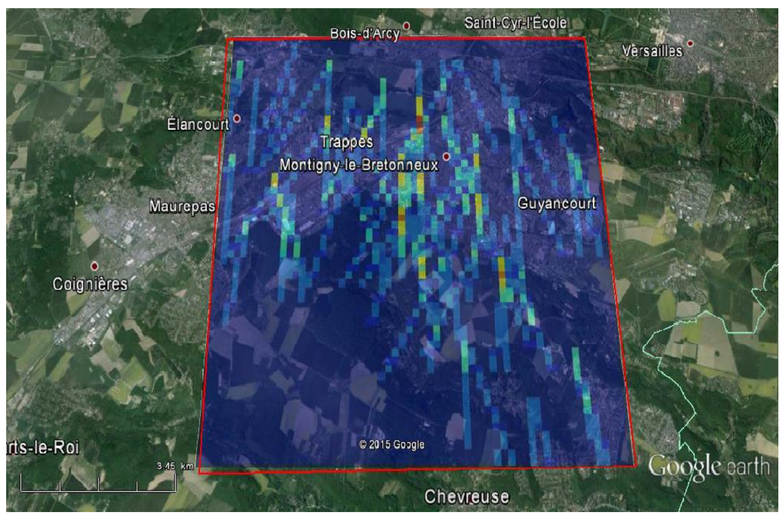


Efficiency of the minimization. Observed (blue) reproduced by the algorithm (red) rainfall time series along the 21 links.

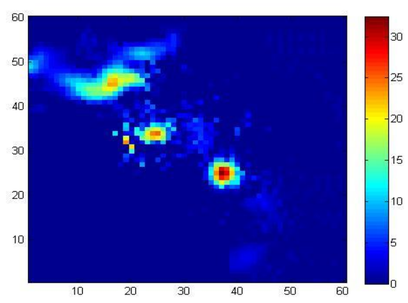
Conclusion & perspectives

- TV-SAT measurements networks can be used in assimilation algorithm to retrieve rainfall fields.
- A large number of links allows estimating original rain field including rain cell structure with a very accurate estimation
- fine scale resolution retrieval (10 s and 500 x 500 m)
- urban area all over the world (conditioned by the presence of TV SAT receivers)
- TV-SAT measurements can be easily merged with other observations type (raingauges) in the assimilation algorithm.

configuration 73 links



Simulation in a suburb area located in Guyancourt near Paris. Colormap corresponds to the number of links per pixel



Retrieved field using 73 links

References :

Mercier, F., Barthes, L., Mallet, C. : Estimation of fine-scale rainfall fields using broadcast TV-SAT links and 4D-VAR assimilation method, Journal of Atmospheric and Oceanic Technology, 2015, accepted.

Barthès L., Mallet C., Rainfall measurement from opportunistic use of Earth-space link in Ku band. Atmospheric Measurement Techniques, 2013, 6 (8), pp.2181-2193.

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